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# EVALUATION OF ARAC'S PARTICIPATION IN A LONG-RANGE TRANSPORT EXPERIMENT

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## 1. INTRODUCTION

The 1994 European Tracer Experiment (ETEX) involved two releases of inert tracer gas in western France, allowing subsequent detection at many locations across Europe. Twenty four operational and research facilities from 20 countries made predictions of the motion of the released plume and the resulting concentrations detected at the sampler locations. This paper describes participation by the Lawrence Livermore National Laboratory's Atmospheric Release Advisory Capability (ARAC) in ETEX. In its role as a real-time emergency response center, ARAC operates a suite of numerical models which simulate the advection and diffusion of airborne releases, and which calculate the estimated downwind concentration of the released material. The models and procedures used by ARAC to participate in ETEX were essentially the same as those which would be used to respond to a release at any previously unspecified location.

## 2. ARAC SYSTEM DESCRIPTION

The mission of the ARAC program is to provide timely and credible estimates of the consequences of atmospheric releases of hazardous materials anywhere in the world (Sullivan et al., 1993). To attain both speed and accuracy, most ARAC responses are accomplished using a suite of computer models, which perform the following functions: 1) construct a block representation of the terrain within the specified domain; 2) interpolate a series of externally-supplied wind data sets, valid at various times, to the model grid; 3) insert the block terrain into the bottom of the model domain, and mass-adjust each of the wind data sets to ensure the flow is over or around terrain, creating a series of three-dimensional wind fields; 4) use the wind fields to simulate advection and diffusion of specified released material; and 5) analyze the concentration of the released material throughout the model domain at specified time intervals. The ARAC system was designed to respond to releases of radioactive materials, so an additional step can estimate doses to humans based on the type of material, etc. This last stage is not applicable to ETEX, which used an inert tracer (perfluoromethylcyclohexane).

Most ARAC responses are for releases whose scale is a few tens of kilometers. Thus our standard model domain for initial responses is 40 km by 40 km with 1 km grid spacing in the horizontal, and 14 layers in the vertical, each 50 m deep. For large-scale scenarios, we use larger grids; for ETEX, the grid was 3000 km by 3000 km with 60 km grid spacing in the horizontal, and 30 layers in the vertical, each 100 m deep.

ARAC system users have considerable control over the performance of the models. Many parameters can be adjusted, allowing various functions to be simulated in quite different ways, or varying how atmospheric stability will affect model calculations. Modelers continue to develop new and better algorithms to accomplish these processes in the system.

## 3. METEOROLOGICAL DATA

The validity and accuracy of ARAC predictions are probably influenced as much by the accuracy and representativeness of input wind fields as by any other factor. For small- or medium-scale releases, we use a variety of observed wind data sources, while for long range dispersion events ARAC depends on externally-supplied gridded wind analyses and forecasts from two sources: the Navy Operational Global Atmospheric Prediction System (NOGAPS), operated by the U. S. Navy's Fleet Numerical Meteorological and Oceanographic Center (FNMOC); and the Global Spectral Model (GSM) used at the Air Force Global Weather

Central. For ETEX, we decided to use NOGAPS data for the first time. The ARAC system automatically acquires, formats, and archives GSM data, but automated procedures to use NOGAPS were not developed, so we created special procedures for this purpose.

The NOGAPS data we received from FNMOC were valid at 1000, 925, 850, 700, 500, 400, and 300 mb, on a 2.5 by 2.5 degree global grid. The data were valid at 12 hr intervals (00 and 12 UTC), and we received a new set of analysis and forecast fields every 12 hr. However, we configured our models to vary the stability-dependent control parameters at 6 hr intervals, to better simulate diurnally-varying processes. Thus we generated new wind fields every 6 hr through the model simulation duration. We repeated this process as each new set of wind data arrived.

Using externally-supplied global gridded data limits the time and space resolution of the wind data input into the ARAC model system, and prevents us from representing developing mesoscale features. To address this situation, we are installing on our computers the Navy Operational Regional Analysis and Prediction System (NORAPS), FNMOC's operational mesoscale prognostic model. We will run NORAPS on our own computers, so we will have access to its forecast values at the actual time and space resolution of the model. We expect NORAPS to produce more accurate forecasts than NOGAPS due to its better resolution and consideration of more boundary-layer processes and other effects. Because of the strong influence of the accuracy of wind data on the accuracy of our predictions, we expect to achieve considerable improvement in our results when we begin to use NORAPS.

## 4. MOTIVATION FOR PARTICIPATION

ARAC had several objectives for participating in ETEX:

• As an operational center, we welcome opportunities to respond in real time to unusual events. Actually the ETEX scenario did not fully exercise ARAC's capabilities, as the location and nature of the releases were known beforehand. A more realistic test would have been to specify the location, time, rate, and nature of the release when the releases began.

• ETEX was a good opportunity to compare the performance of our operational system, with its requirements for relocatability and flexibility, to that of research centers whose mission allows fine-tuning of specialized models for a previously-defined scenario. Additionally, the operational ARAC configuration in 1994 was based on global forecast model data, while many ETEX participants used specially-configured regional-scale models.

• The ETEX measurement data will be a valuable tool for systematic evaluation of future model developments.

## 5. SYSTEM CONFIGURATION FOR ETEX

In keeping with our objective to evaluate our actual operational capabilities, we used our routine day-to-day system as much as possible. Except for expanding the model grid, we used our standard operational model components, and the only alteration we made to our normal procedures was to acquire NOGAPS data.

## 6. ETEX PROCEDURES

The two ETEX tests involved surface releases from a location in Rennes, France (Girardi et al., 1995) on 23 Oct 94 and 14 Nov 94. For each release, participants generated the first set of forecasts of 3-hr average concentrations at each sampler location at 3 hr intervals, starting at 3 hr after the release and extending out to 60 hr. The second set of forecasts started 12 hr after the release, using the next valid set of wind analyses and forecasts, and extending out to the same ending time. Each subsequent set of forecasts started 12 hr later, using new wind data, and ending at the same time. Thus, each set of forecasts was 12 hr shorter than the previous one. To link the forecasts in this way, we used a feature of ADPIC which generates a "restart" file within each run; this restart file was used as initial conditions for the next run (Pace et al., 1995). During actual large-scale responses, such as that for the Kuwaiti oil fires (Ellis et al., 1992, Sullivan et al., 1992) we use a similar stepwise procedure to update our forecasts as new wind information becomes available. A final set of calculations used only the analysis data (no forecasts) collected every 12 hr through the exercise period.

In addition to the forecasts of concentrations at each sampler, we generated contour plots showing the concentration pattern at various times, including the ending time of the experiment. The amount of change in the final plot, as our input wind fields became progressively better (i.e., shorter forecasts), is a crude indicator of the accuracy of the input wind fields and of our model forecasts. For comparison, we reran our models based on GSM data, and we found the results based on NOGAPS data (Figure 1) were more consistent than those based on the GSM (Figure 2).

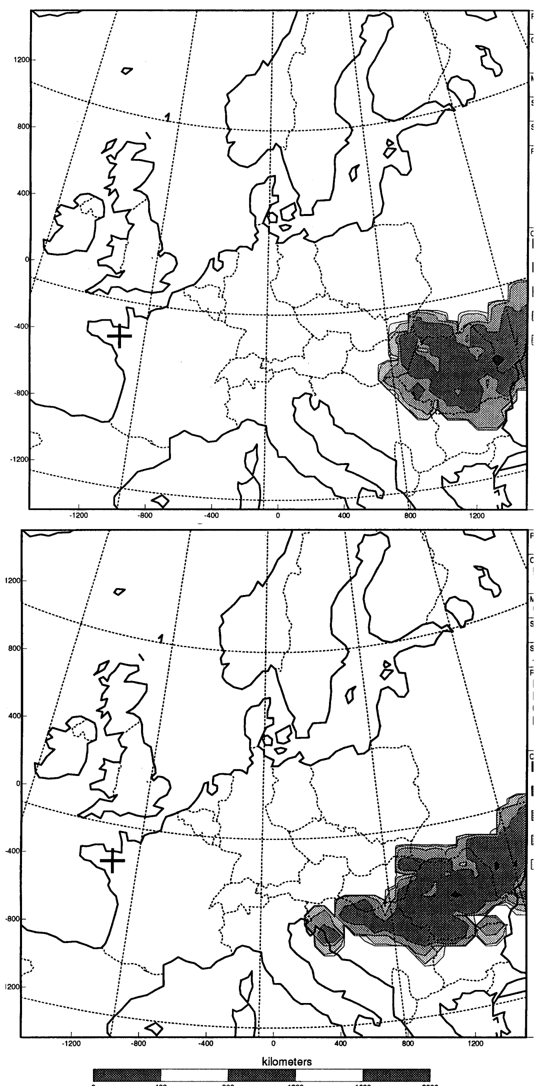


Fig. 1. Comparison of concentration plots from initial run (top) and final run (bottom), both valid at 03 UTC on 17 Nov 94 (60 hr following the second release). Runs based on NOGAPS wind data.

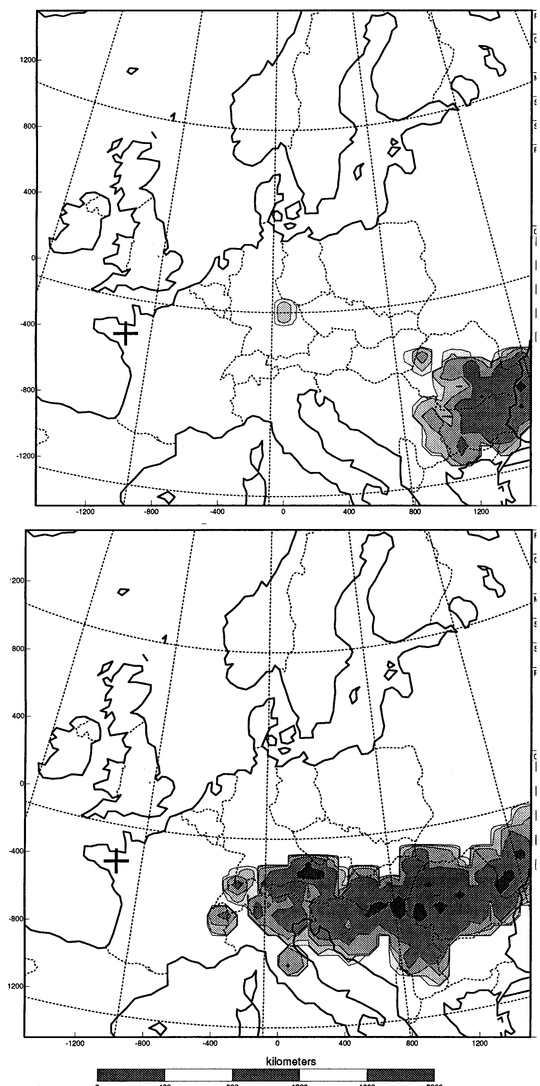


Fig. 2. Comparison of concentration plots from initial run (top) and final run (bottom), both valid at 03 UTC on 17 Nov 94 (60 hr following the second release). Runs based on GSM wind data.

We responded to the ETEX releases in essentially the same way we would for a large-scale release at any previously unspecified location. We retrieved the required wind data, specified the location and release rate, and modified our control files to account for time-varying conditions. For the first release, we accomplished all these tasks and completed our initial model execution within 3 hr of notification. Our response to the second release was considerably faster (approximately 2 hr) as we had streamlined our procedures to acquire NOGAPS data.

Our initial response time for smaller-scale releases is much faster, generally 15 min or less at pre-defined locations. The extra time needed for ETEX was due to several factors. Typically we use only one wind field for our initial response, but we generated 11 wind fields (analysis plus ten 6-hr forecasts) for the initial 60-hr forecast, and then mass-adjusted each one. We generally use wind data already resident in our system databases, but use of the NOGAPS data required special processing steps. The large grid domain required much more processing time than is needed by our small-scale grids, and a 60 hr ADPIC run is much longer than our standard executions (generally 2-4 hr). For an actual large-scale emergency, we would eliminate many of these processes for our initial run, and could reasonably expect to generate a useful product within an hour of notification.

## 7. STATISTICAL EVALUATION

An important aspect of the ETEX project is to perform statistical comparisons of model forecasts with actual sampler values. The evaluation process is underway, and results are expected in late 1995.

This evaluation of the ARAC models will be the latest of more than a dozen tracer studies over the last two decades (Foster and Dickerson, 1990; Sullivan et al., 1993), including several on long-range (1000-5000 km) scales:

- 1983 Cross-Appalachian Tracer Experiment (CAPTEX) (Rodriguez, 1987).
- 1987 Across North America Tracer Experiment (ANATEX) (Rodriguez and Cederwall, 1991; Rodriguez et al., 1995).
- 1989-91 Atmospheric Transport Model Evaluation Study (ATMES) using measurements from the 1986 Chernobyl accident (Lange and Foster, 1993).

These studies have demonstrated the strong influence of the accuracy of meteorological data on overall model performance. For example, Rodriguez (1987) found that performance statistics are often poor when observations and predictions are paired in time and space (i.e., the approach followed in ETEX), mainly due to misalignment of the plume centerline which can be caused by small errors in wind direction observations.

The ETEX results will yield an interesting evaluation of the accuracy of the ARAC system as it was in 1994. However, a more significant motivation for ARAC participation in ETEX was the opportunity to evaluate developments and refinements of our models.

Foster (1994a,b) has created a sophisticated model evaluation system which allows statistical evaluation of the changes in performance of the ARAC models as new algorithms are developed or as model control parameters are adjusted. The system archive currently contains data from seven pre-ETEX field studies (Foster, 1995), and we plan to use the ETEX sampler measurements in this system when they become available to study our model response to various control parameter values, and to evaluate the effects of future model developments and improvements. In particular we expect to use NORAPS wind forecasts to repeat our calculations for one ETEX release.

## 8. OVERALL EVALUATION

Although the statistical results are not yet available at the time this paper is written, ARAC's participation in ETEX as measured against our objectives was clearly a success. The ARAC operational system easily accomplished the runs and delivered products within the specified time; we will be able to compare our results (both statistical and graphical) with those of other organizations; and we anticipate routine future use of the measurement values in our model evaluation software. Further, our participation motivated us to develop procedures to acquire and use NOGAPS data, and to accelerate our efforts to install a prognostic model on our system.

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